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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

TAKE-OFF AND LANDING CHARACTERISTICS OF A 0.13-SCALE
MODEL OF THE CONVAIR XFY-1 VERTICALLY RISING
AIRPLANE IN STEADY WINDS

TED NO. NACA DE 368

By Robert O. Schade, Charles C. Smith, Jr.,
and P. M. Lovell, Jr.

Langley Aeronautical Laboratory
Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
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SUMMARY

An experimental investigation has been conducted to determine the stability and control characteristics of a 0.13-scale free-flight model of the Convair XFY-1 airplane during take-offs and landings in steady winds. The tests indicated that take-offs in headwinds up to at least 20 knots (full scale) will be fairly easy to perform although the airplane may be blown downstream as much as 3 spans before a trim condition can be established. The distance that the airplane will be blown downstream can be reduced by restraining the upwind landing gear until the instant of take-off. The tests also indicated that spot landings in headwinds up to at least 30 knots (full scale) and in crosswinds up to at least 20 knots (full scale) can be accomplished with reasonable accuracy although, during the landing approach, there will probably be an undesirable nosing-up tendency caused by ground effect and by the change in angle of attack resulting from vertical descent. Some form of arresting gear will probably be required to prevent the airplane from rolling downwind or tipping over after contact. This rolling and tipping can be prevented by a snubbing line attached to the tip of the upwind wing or tail or by an arresting gear consisting of a wire mesh on the ground and hooks on the landing gear to engage the mesh.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, an investigation is being conducted to determine the dynamic stability and control characteristics of a 0.13-scale flying model of the Convair XFY-1 vertically rising airplane. As a part of this investigation, tests have been made to determine the take-off and landing characteristics. References 1 and 2 give the results of take-offs and landings in still air, while the present paper gives results of take-offs and landings in steady winds. In the present investigation, take-offs were made in headwinds with and without restraining gear, and landings were made in both headwinds and crosswinds with and without arresting gear.

The results of the investigation were obtained mainly from the pilots' observations of the stability and controllability and general flight behavior of the model. As an aid in the study of some of the particular phases of the behavior of the model, however, time histories of the motions of the model have been prepared from motion-picture records of some of the flights.

NOMENCLATURE AND SYMBOLS

In order to avoid confusion in terminology which might arise because of the unusual operating attitudes of the model, it should be explained that the controls and motions of the model are referred to in conventional terms relative to the body system of axes; that is, the rudders on the vertical tails produce yaw about the normal (Z) axis, differential deflection of the elevons on the wings produce roll about the fuselage (X) axis, simultaneous up or down deflection of elevons produces pitch about the spanwise (Y) axis. Figure 1 shows the axes and the positive directions of linear and angular displacements.

The definitions of the symbols used in the present paper are as follows:

X	fuselage axis
Y	spanwise axis
Z	normal axis
I_X	moment of inertia about fuselage axis, slug-ft ²
I_Y	moment of inertia about spanwise axis, slug-ft ²

I_Z	moment of inertia about normal axis, slug-ft ²
\bar{c}	mean aerodynamic chord, ft
θ	angle of pitch of fuselage axis relative to horizontal, deg
ψ	angle of yaw, deg
ϕ	angle of bank, deg
β	angle of sideslip, deg
α	angle of attack of fuselage axis, deg
δ_r	rudder deflection (positive when deflected to left), deg
δ_a	total differential deflection of elevons (positive when left surface is deflected down and right surface is deflected up), deg
δ_e	simultaneous up or down deflection of elevons (positive when deflected down), deg
V_z/V_{S_∞}	velocity ratio
V_z	wind velocity
V_{S_∞}	average theoretical velocity of propeller slipstream at a large distance behind propeller disk, $\sqrt{8T/\pi\rho D^2}$
ρ	mass density of air, slugs/cu ft
S	wing area, sq ft
T	thrust, lb
D	propeller diameter, ft
$C_m = \frac{\text{Pitching moment}}{q_{S_\infty} S \bar{c}}$	
q_{S_∞}	dynamic pressure of propeller slipstream, $4T/\pi D^2$

MODEL

A photograph of the model is shown in figure 2 and a sketch giving some of the more important dimensions is shown in figure 3. More detailed dimensions are given in table I. The model had a modified-triangular wing, modified-triangular vertical-tail surfaces mounted symmetrically above and below the fuselage, and an eight-blade, dual-rotating, fixed-pitch propeller (two four-blade elements in tandem) powered by a 5-horsepower electric motor. For the landing tests, metal shock struts similar to those used in reference 2 were installed on the model. The important geometric characteristics of the shock struts are presented in table I. For the take-off tests, rigid wooden blocks were used instead of the shock struts. The model does not represent the final configuration of the airplane since it was constructed before the final design revisions were made. Moreover, the model was not exactly a 0.13-scale model of the original design in all respects, since it was designed from some rather small drawings and some slight inaccuracies occurred in obtaining dimensions. It is believed, however, that the differences between the model and the final airplane configuration are not great enough to alter appreciably the results presented in this paper.

The center of gravity was approximately at the design location, 0.15 mean aerodynamic chord and 5.0 inches (full scale) above the thrust line. The weight and moments of inertia of the model scaled up to full scale are shown in the following table:

	Weight, lb	I_x , slug-ft ²	I_y , slug-ft ²	I_z , slug-ft ²
Model (without shock struts)	16,000	10,900	25,000	29,000
Model (with shock struts)	18,320	19,152	37,310	43,380
Airplane	16,250	12,016	23,361	30,647

Maneuvering was accomplished by means of flap-type elevons and rudders operating in the propeller slipstream with the following control deflections, measured from the control position required for trim flight:

Total differential deflection of elevons, δ_a , deg ± 54
 Simultaneous deflection of elevons, δ_e , deg ± 25
 Rudder deflection, δ_r , deg ± 25

These controls were remotely operated by the pilots and were deflected by flicker-type (full-on, full-off) pneumatic servomechanisms which were controlled by electric solenoids. The servomechanisms were equipped with

integrating-type trimmers which, with each control application, changed the trim a little in the direction that the pilot applied his control. The values shown in the preceding table are for deflections from the trim position. For example, when the elevons were trimmed down 15° for forward flight, the surfaces were deflected to 40° down and 10° up for elevator control. Three separate pilots were used to control the model in pitch, roll, and yaw in order that they might give careful attention to the motions of the model about each of the axes.

APPARATUS AND TESTS

The investigation covered in the present paper consisted entirely of flight tests of the model. The stability and controllability of the model were determined mainly from the pilots' observations, although motion-picture records were made of all flights for future study of the behavior of the model. A quantitative indication of the controllability was also obtained from time histories of the motions of the model taken from the motion-picture records.

Headwind and Crosswind Landings

The landing tests were made in steady headwinds of approximately 20 to 30 knots (full scale) and in crosswinds of approximately 10 to 20 knots (full scale). The first few attempts at headwind landings were made using a technique suggested by Convair as being desirable from the standpoint of landing loads. This technique involved an approach in which the model started from a position above and downwind of the landing area, then simultaneously descended and moved upwind to the landing spot and flared for a four-point landing with no forward velocity relative to the ground at touchdown. The remainder of the landings were made using a somewhat simpler technique, which consisted of flying to a position directly above the landing area and then decreasing the speed of the propellers so that the model descended slowly until the lowest landing gear was about 12 inches from the ground. At this point the power was cut off completely and the model dropped to the ground. The ground in this case was the tunnel ground board, which has a smooth wooden surface. All the landing tests were made with the shock struts installed, and for all landings except those in a wire-mesh arresting gear the shock struts were equipped with hardwood casters. Landings were made with the brakes on the wing-tip wheels locked and unlocked.

Two types of arresting devices were also tried in the landing tests. One arresting device was a snubbing line attached to the model either at the rear of the fuselage or at the tip of the upwind landing gear as illustrated in figure 4. The snubbing line was slack during the landing

approach and was pulled tight as the model made contact with the ground. The other arresting device tried in the tests consisted of a wire mesh mounted close to the ground and hooks on the landing gear for engaging the mesh. The general idea for this scheme was suggested by Convair. The wire mesh used in the tests represented a 36-foot-square grid of 0.47-inch-diameter wire forming 17-inch squares 14 inches above the ground. The hooks that were attached to the bottom of the landing gear in place of the casters are shown in figure 5 along with some of the pertinent full-scale dimensions. These hooks act as barbs in that they can be forced through the mesh, either by bending the hooks or by spreading the wire of the arresting gear, but would not come out of the mesh if the airplane tended to tip over.

Headwind Take-Offs

Headwind take-offs were made in winds of approximately 10 to 20 knots (full scale) with and without restraint on the upwind landing gear. The unrestrained take-offs were made by establishing the desired airspeed and then rapidly increasing the speed of the propellers until the model took off. After take-off the speed of the propellers was adjusted so that steady flight would be obtained at a height of approximately 15 feet. In the restrained take-offs, a quick-release device was attached to the upwind landing gear to prevent the model from taking off until the power operator had time to bring the model up to maximum thrust.

All take-offs were made with the model lightened by the use of wooden blocks in place of the metal shock struts. With the model in this condition the maximum static thrust was approximately 5 percent greater than the weight of the model.

RESULTS AND DISCUSSION

The results of the present investigation are illustrated more graphically by motion pictures of the flights of the model than is possible in a written presentation. For this reason a motion-picture film supplement to this paper has been prepared and is available on loan from the NACA Headquarters, Washington, D. C.

Longitudinal Stability and Trim

During take-offs and landings the model exhibited an undesirable nosing-up tendency which was more pronounced when the model was close to the ground. Before discussing the effect of this characteristic on the behavior of the model in take-offs and landings, it is desirable to

examine some force-test data which will help explain the results obtained in flight. These force tests were made by Convair on a 0.15-scale model in headwinds and are reported in reference 3. The pertinent data from this report are replotted in figures 6 to 8 in a form which facilitates the present analysis.

A possible reason for the nosing-up tendency during the landing approach when the model was well above the ground was the rather large change in angle of attack resulting from vertical descent. As an example, assume that the airplane is hovering in a headwind of 23 knots ($V_z/V_{S_\infty} = 0.14$) at a trim angle of attack of 70° . If a vertical landing approach is then made with a rate of descent of 10 feet per second and the angle of pitch remains constant, the angle of attack will increase from 70° to 90° . The data of figure 6 show that this change in angle of attack would cause a change in the trim elevator setting from approximately 8° to 30° .

As the model approached the ground, additional nosing-up moments were produced by ground effect. The data of figure 7 for a velocity ratio V_z/V_{S_∞} of 0.14 (forward speed 23 knots full scale) show that as the model approached the ground an increasing amount of down elevator was required for trim. At the higher angles of attack resulting from vertical descent (80° or 90°), more elevator deflection was required than was available when the model was near the ground. Since the control-effectiveness data of figure 8 indicate that the increased down elevator required was not the result of decreased elevator effectiveness, it apparently was the result of an increase in nose-up pitching moment caused by ground effect for a constant elevator setting and angle of attack.

Landings

The general results obtained in these tests indicated that spot landings in headwinds up to at least 30 knots (full scale) and in crosswinds up to at least 20 knots (full scale) can be performed with reasonable accuracy. The airplane is likely to be blown off the spot after touchdown, however, either by tipping over in the headwind landings or by rolling downwind in crosswind landings unless a suitable arresting gear is used. The crosswind speed was limited in the landing tests to a maximum value of 20 knots (full scale) by the tendency of the model to diverge in roll. (See ref. 4.) The landing characteristics will be discussed in detail in the following paragraphs.

Landing approach.- The flared approach suggested by Convair was used for the first landing attempts but this technique appeared to require more precision than could be readily acquired by a pilot and a

power operator flying a remotely controlled model. As a result, the remainder of the spot landings were made using a somewhat simpler technique, which consisted of starting the landing directly over the landing area and then descending vertically to a landing. By using this technique, spot landings in headwinds could be accomplished with reasonable accuracy but the model quite often diverged in pitch during the final approach because of the undesirable nosing-up tendency previously mentioned. The pitch pilot had sufficient elevator power to prevent nosing up only if he anticipated a large nose-up change in trim when the model was at a height corresponding to approximately 20 feet from the ground (full scale) and applied full down elevator for the remainder of the descent. Two such landings are shown in figure 9 in the form of time histories of elevator deflection from trim setting, angle of pitch, and height above ground. Notice that the pilot applied full down elevator before the model had nosed up very far or had approached very close to the ground, and a successful touchdown was made. Since it was quite difficult to anticipate the large nose-up change in trim and to determine the exact height at which to apply full down elevator with the flicker-type control system used, and since the response to elevator deflection was slow near the ground, the model sometimes inadvertently pitched up during the final landing approach. Time histories for two such landings are presented in figure 10. In these cases the model had descended too close to the ground and had built up too great a nose-up pitching velocity. Analysis indicated that the nosing-up difficulty could be partly attributed to the fact that the model required a fairly large down elevator deflection for trim (approximately 15°) in forward flight at 23 knots (full scale) and that the 25° down elevator control deflection from this trim position resulted in operation of the control surface in a range of decreased effectiveness. (The fact that the model required more down elevator for trim than that shown in the data of figure 6 can be at least partly explained by the nose-up pitching moment produced by the propeller guard and safety cable.) In order to determine whether smaller down elevator trim settings would decrease the pitch-up tendency, the model was flown inverted (canopy toward the wind) so that the offset center of gravity would result in lower rather than higher elevator deflections. In these tests in which the elevator deflection for trim was approximately 3° up, the nose-up tendency during the landing approach was still apparent but the pilot had much less difficulty in preventing the model from nosing up. This result indicates that the behavior during the landing approach might be improved if the large down elevator deflections required for trim could be reduced by relocating the center of gravity closer to the thrust line. If the trim elevator setting for the airplane for the 23-knot forward flight condition is 8° down (as indicated by force tests) instead of 15° down, its pitch-up difficulties should be less severe than those of the model. Another difference, which might offset this effect, is that the maximum down elevator deflection available for the airplane is 30° whereas that for the model is approximately 40° .

In the crosswind landings, which were made at airspeeds somewhat lower than for the headwind landings, the model also had an undesirable nosing-up tendency but satisfactory spot landings could be performed fairly easily, as shown in the time histories of some typical landings in figure 11. The nosing-up tendency exhibited by the model during vertical descents was not as severe as that observed in the headwind landings and there appeared to be no appreciable increase in nosing-up tendency as the model neared the ground.

Behavior at touchdown.- The behavior of the model at touchdown in both headwind and crosswind spot landings was considered unsatisfactory. In the headwind landings the model tipped over after contact and had to be retrieved by means of the safety cable, whereas in the crosswind landings the model was blown off the spot by rolling downstream. Locking the brakes on the two wing-tip wheels considerably reduced the landing roll in the crosswind landings but the model still tipped over in the headwind landings. More braking action could undoubtedly have been obtained if four instead of two brakes had been locked and if rubber instead of hardwood wheels had been used. The tendency to tip over or roll downwind was probably more severe for the model than it will be for the full-scale airplane because of the additional drag and nose-up pitching moment produced by the propeller guard and safety cable of the model.

The tendency of the model to tip over or to roll downwind after contact indicates that the use of some type of arresting device will be necessary to permit operation of the airplane when there are fairly high ground winds. The tests with the snubbing lines and the wire-mesh arresting gear were made, therefore, to provide some basic information for these two methods of preventing tipping or rolling after touchdown.

The concept of the snubbing-line system is that the airplane carry a line that can be lowered to the ground when the landing approach is being made and that a device on the ground take up the excess slack during the landing approach and pull the line taut as the airplane touches down. The snubbing line should not be pulled taut when the airplane is at an appreciable height above the ground, since the data of reference 1 indicate that this procedure might result in instability of the airplane. It is evident that if such a snubbing line is to prevent overturning, the airplane should land so that the attachment point on the airplane is as near as possible to the attachment point on the ground. As pointed out previously, in one of the arrangements covered in the tests the snubbing line was attached to the rear of the fuselage and in the other arrangement the snubbing line was attached to the tip of the upwind gear as shown in figure 4.

The use of the snubbing line attached to the rear of the fuselage was unsatisfactory because in both headwind and crosswind landings the

model tipped over after contact when the snubbing line was pulled taut. In fact, the use of the snubbing line seemed to aggravate the tendency of the model to tip over. Theoretically this system should be satisfactory in preventing the model from tipping over and rolling downwind if the model is landed with the rear of the fuselage directly over the ground attachment point of the snubbing line and the line pulled taut immediately after touchdown. In actual practice this could not be done with the model. The model either failed to land directly over the attachment point, or the line stretched too much or could not be pulled taut quickly enough after touchdown.

With the snubbing line attached to the tip of the upwind landing gear, satisfactory landings could be made in either headwinds or crosswinds. The snubbing line effectively prevented the model from tipping over or rolling downwind after touchdown. During the landings where the snubbing line was attached to the tip of the upwind landing gear, the model usually pitched up and drifted back during the final approach and the line became taut just before the model touched down. This tightening of the line, however, did not seem to cause any detrimental effects.

The use of the wire-mesh arresting gear was considered satisfactory in both headwind and crosswind landings, provided the hooks on the landing gear caught in the wire mesh. Satisfactory landings could be made even where moderate pitch-up (θ up to 90°) occurred before contact. In a few cases both in headwind and crosswind landings, however, a satisfactory approach was made but the upwind gear hit directly on top of a wire and bounced instead of going through the mesh. After this initial bounce the model would sometimes settle back into the mesh and the landing-gear hooks would catch in the mesh for a successful landing. At other times, however, the model would tip over and have to be retrieved by the safety cable. This failure of the model to engage the mesh at times does not necessarily indicate a fundamental fault of this type of arresting gear, since it is probable that by proper design of the contact surface at the bottom of the landing gear this difficulty could be eliminated.

Headwind Take-offs

In general, take-offs in headwinds up to at least 20 knots (full scale) could be accomplished with little difficulty but the model was blown downstream a distance of several spans before a trim condition could be established. The amount the model was blown downstream could be reduced by restraining the upwind landing gear until take-off. The headwind speed for the take-off tests was limited to a maximum value of approximately 20 knots (full scale) with the particular test setup used, since at airspeeds much greater than this the model was blown downstream

so far that successful take-offs could not be accomplished. A detailed discussion of the take-off characteristics is given in the following paragraphs.

Take-offs in headwinds of approximately 15 to 20 knots (full scale) without a restraining gear were fairly easy to perform but, as shown in the time histories of the take-offs in figure 12, the model was blown downwind approximately 3 spans (70 to 75 feet full scale) before the nose could be brought down and a trimmed flight condition established. Some of the downstream drift occurred even before the model took off. In order to stop this downstream drift as soon as possible, the pitch pilot applied full down elevator before take-off and held it until he thought he had rotated the model to its trim pitch angle or had built up enough angular momentum to rotate it to that angle. With the wooden-block landing gear used in the take-off tests the model might be considered as representing a brakes-locked condition. Brakes are not very effective during take-offs, however, because of the increased aerodynamic drag and reduced ground friction as the thrust increases.

At reduced headwind velocities, of course, the model was not blown downstream as far. The results in figure 13 indicate that for a lower headwind velocity of approximately 10 knots (full scale) the model was blown back only about 2 spans (50 to 55 feet full scale) as compared with approximately 3 spans (70 to 75 feet full scale) at a velocity of approximately 20 knots (full scale).

In an effort to reduce the amount the model was blown downstream at the higher headwind velocities (approximately 15 to 20 knots full scale), tests were made in which the upwind landing gear was restrained until take-off. Sample time histories from these tests presented in figure 14 show that restraining the landing gear until take-off reduced the distance the model was blown downstream to approximately 30 feet (full scale).

A pictorial summary of the results of take-off tests is presented in figure 15. In the unrestrained take-off shown in figure 15(a), the model pitched in a nose-up direction as it first left the ground despite the fact that down elevator was being applied. This was caused by the fact that the model rotated about the landing gear rather than the center of gravity when on the ground, and by the fact that there was an insufficient amount of down elevator deflection during the initial portion of the take-off. After the model had left the ground and picked up some height and vertical velocity, however, the model began to pitch down rapidly toward its trim pitch angle. At a lower speed (fig. 15(b)) the nosing-up tendency was not as severe as the model first left the ground. During the initial portion of the take-off the model rotated rather slowly towards its trim pitch angle but, as in the previous case, it began to pitch rapidly after it had left the ground and picked up vertical speed. With the upwind landing gear restrained until maximum

thrust was developed (fig. 15(c)) the model ascended through the region of severe nose-up tendency much more rapidly than when unrestrained.

Take-off characteristics of the airplane might be expected to be somewhat better than those obtained in these tests because of the additional excess thrust that will be available for the airplane. This additional thrust will only be beneficial, however, if maximum thrust can be developed quickly or if the airplane is tied down until maximum thrust is developed.

SUMMARY OF RESULTS

The following major results were obtained from the flight tests of a 0.13-scale flying model of the Convair XFY-1 vertically rising airplane during take-offs and landings in steady winds.


1. Take-offs in headwinds up to at least 20 knots (full scale) were fairly easy to perform although the model was blown downstream as much as 3 spans before a trim condition could be established. Restraining the upwind landing gear until the take-off resulted in a reduction in the distance the model was blown downstream.
2. Spot landings in headwinds up to at least 30 knots (full scale) and in crosswinds up to at least 20 knots (full scale) were accomplished with reasonable accuracy but the model tended to roll downstream or tip over after touchdown. This rolling and tipping could be prevented by either a snubbing line attached to the upwind landing gear or an arresting gear consisting of wire mesh on the ground and hooks on the landing gear.
3. Although it was possible to make spot landings by proper use of the controls, an undesirable nosing-up tendency was evident which was

caused by ground effect and by the change in angle of attack resulting from vertical descent.

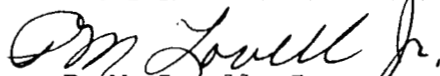
Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., June 1, 1954.


Robert O. Schade

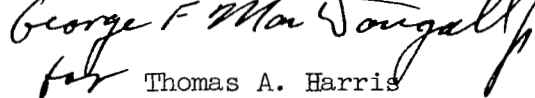
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Chief of Stability Research Division

ecc

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TABLE I.- GEOMETRIC CHARACTERISTICS OF THE MODEL

Weight without shock struts, lb	35.00
Weight with shock struts, lb	40.00
<u>Wing</u> (modified triangular plan form)	
Sweepback, deg	55.00
Airfoil section	NACA 63-009 modified
Aspect ratio	1.90
Taper ratio (root to theoretical tip)	5.23
Area (total to center line), sq in.	818.95
Span (theoretical), in.	39.49
Mean aerodynamic chord, in.	23.94
Span of elevon (each), in.	15.37
Chord of elevon, in.	2.92
Dihedral angle, deg	0
Overall length of model, in.	49.40
Fuselage length, in.	45.40
<u>Vertical tails</u> (modified triangular plan form)	
Sweepback, deg	40.00
Airfoil section	NACA 63-009 modified
Aspect ratio	3.18
Taper ratio (root to theoretical tip)	3.15
Area (total to center line), sq in.	397.88
Span, in.	34.73
Mean aerodynamic chord, in.	13.07
Span of top rudder, in.	14.13
Span of bottom rudder, in.	11.13
Chord of rudders, in.	2.85
<u>Propellers</u> (eight-blade dual-rotating)	
Diameter, in.	23.85
Hamilton standard design drawing number	3155-6-1.5
Solidity, one blade	0.0475
Gap, in.	3.00
<u>Shock-absorbing landing gear</u>	
Stroke (maximum), in.	2.83
Stroke under lg load, in.	Approx. 2.13

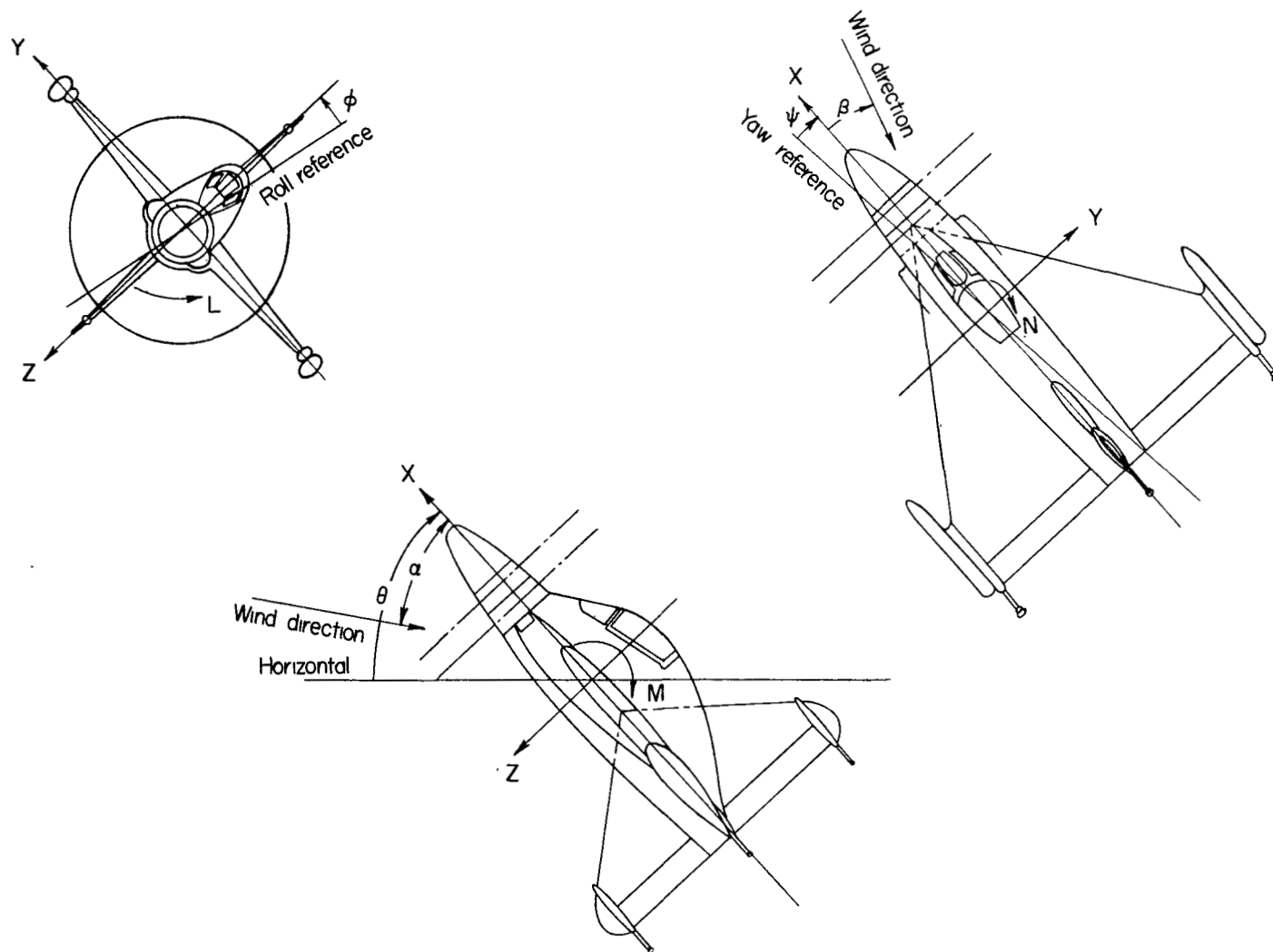
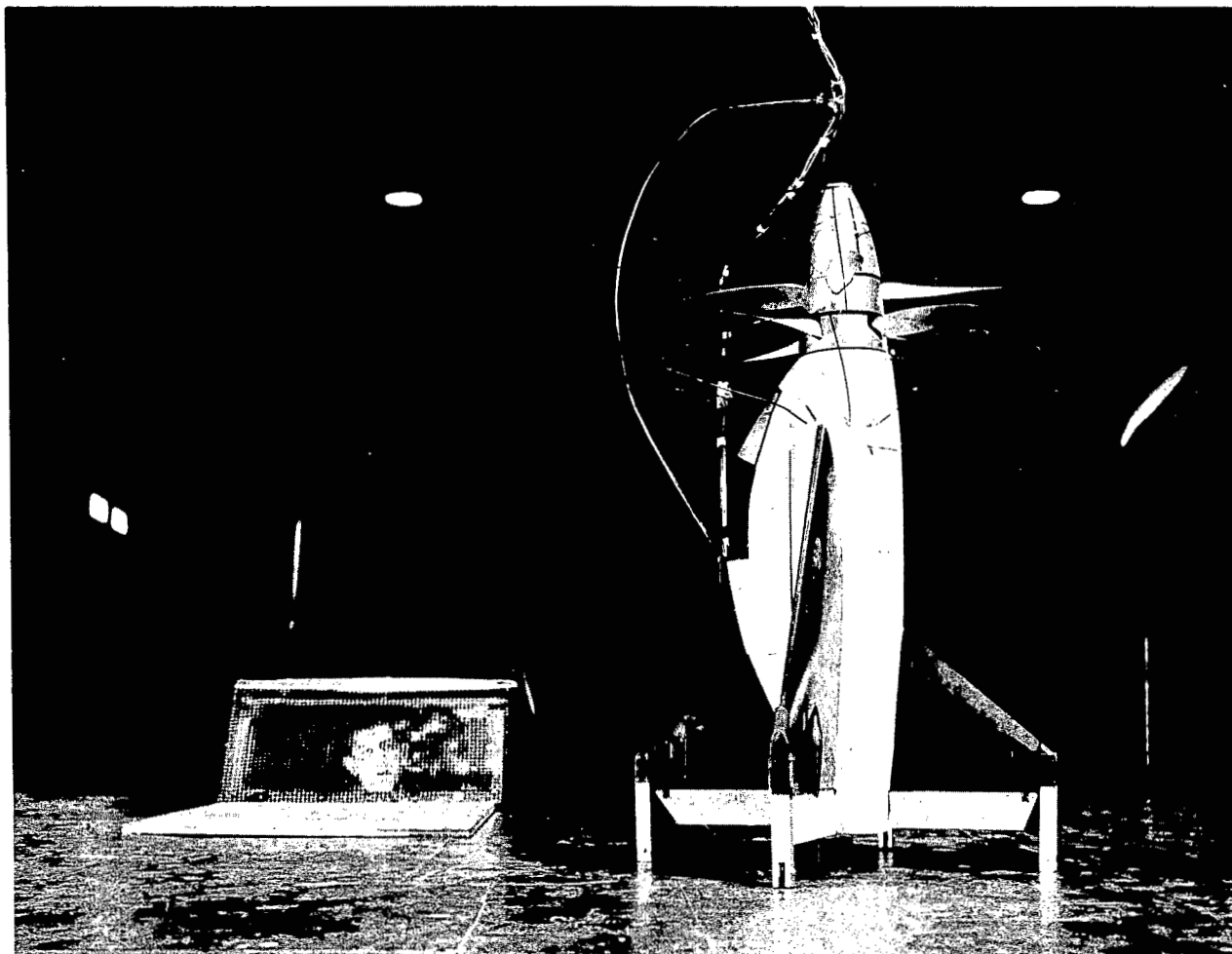


Figure 1.- The body system of axes. Arrows indicate positive directions of forces, moments, and linear and angular displacements.



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Figure 2.- Model on ground board of Langley full-scale tunnel showing wooden blocks used in place of shock struts for take-offs.

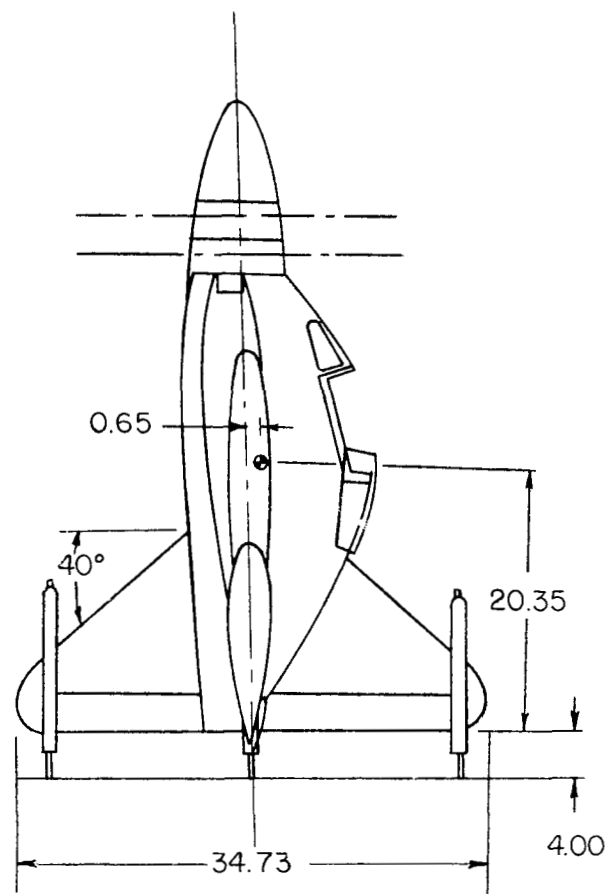
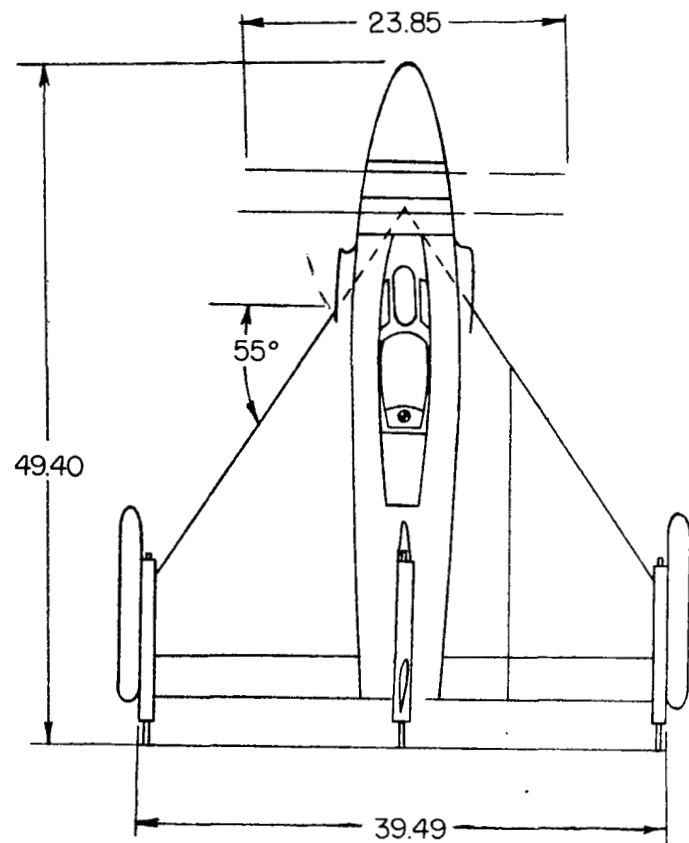
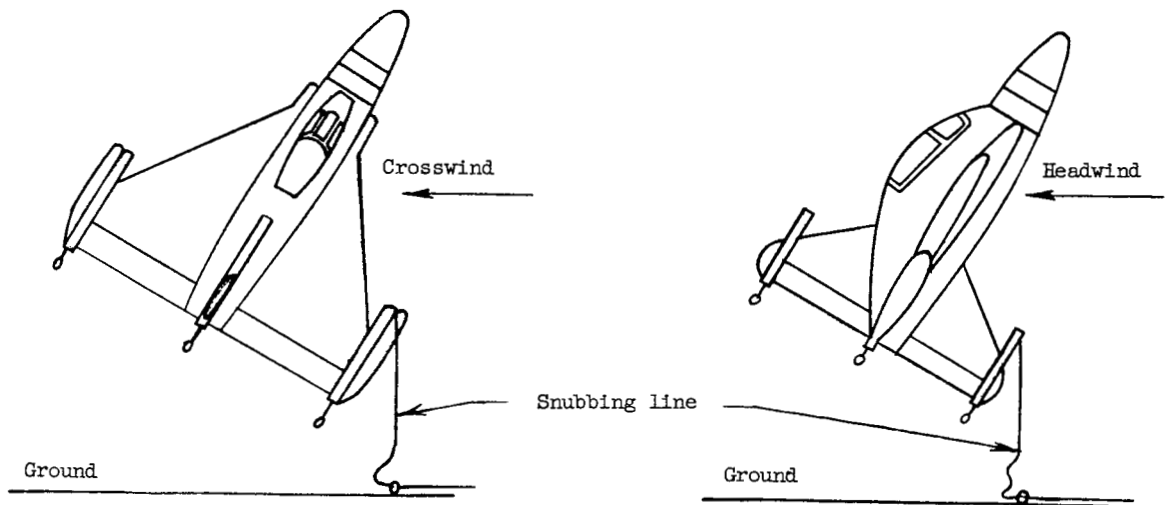
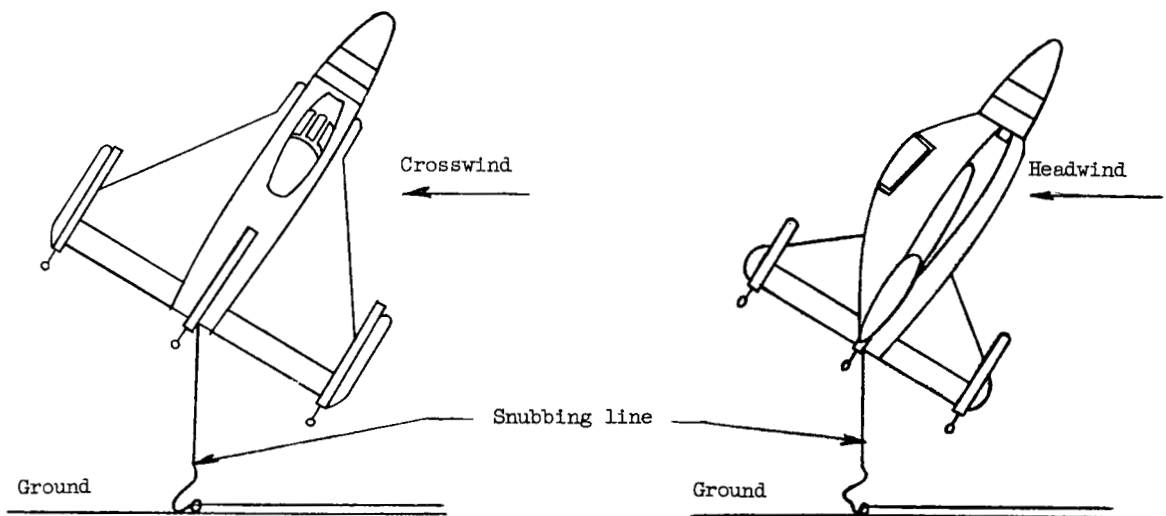


Figure 3.- The XFY-1 vertically rising airplane model. All dimensions are in inches.

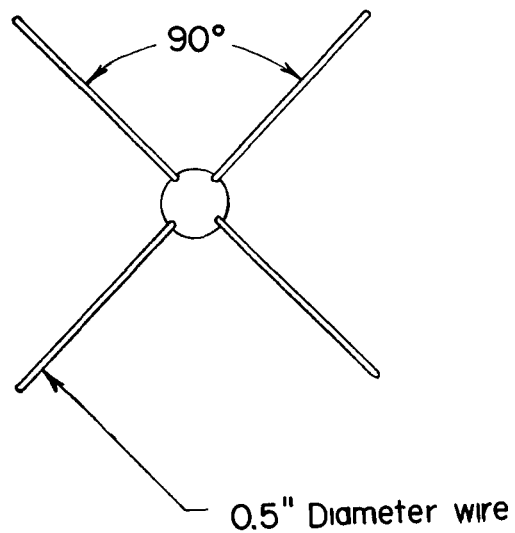


(a) Snubbing line attached to tip of upwind gear.

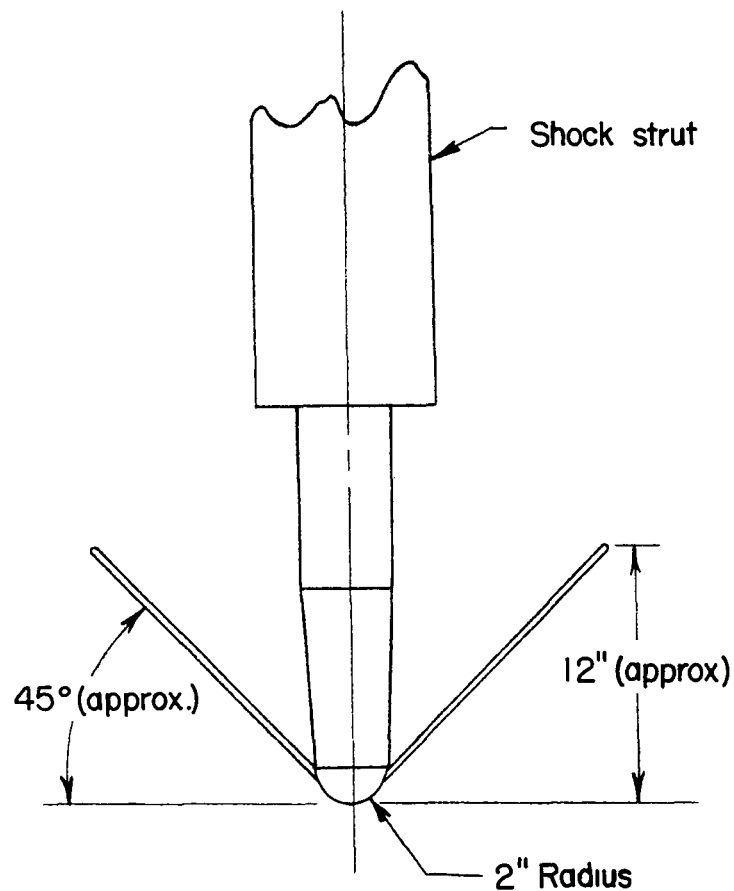


(b) Snubbing line attached to rear of fuselage.

Figure 4.- Snubbing-line arrangements used in the headwind and crosswind landing tests.



Bottom view



Side view

Figure 5.- Detail of hook arrangement used on bottom of shock struts during landings in wire mesh (dimensions are full scale).

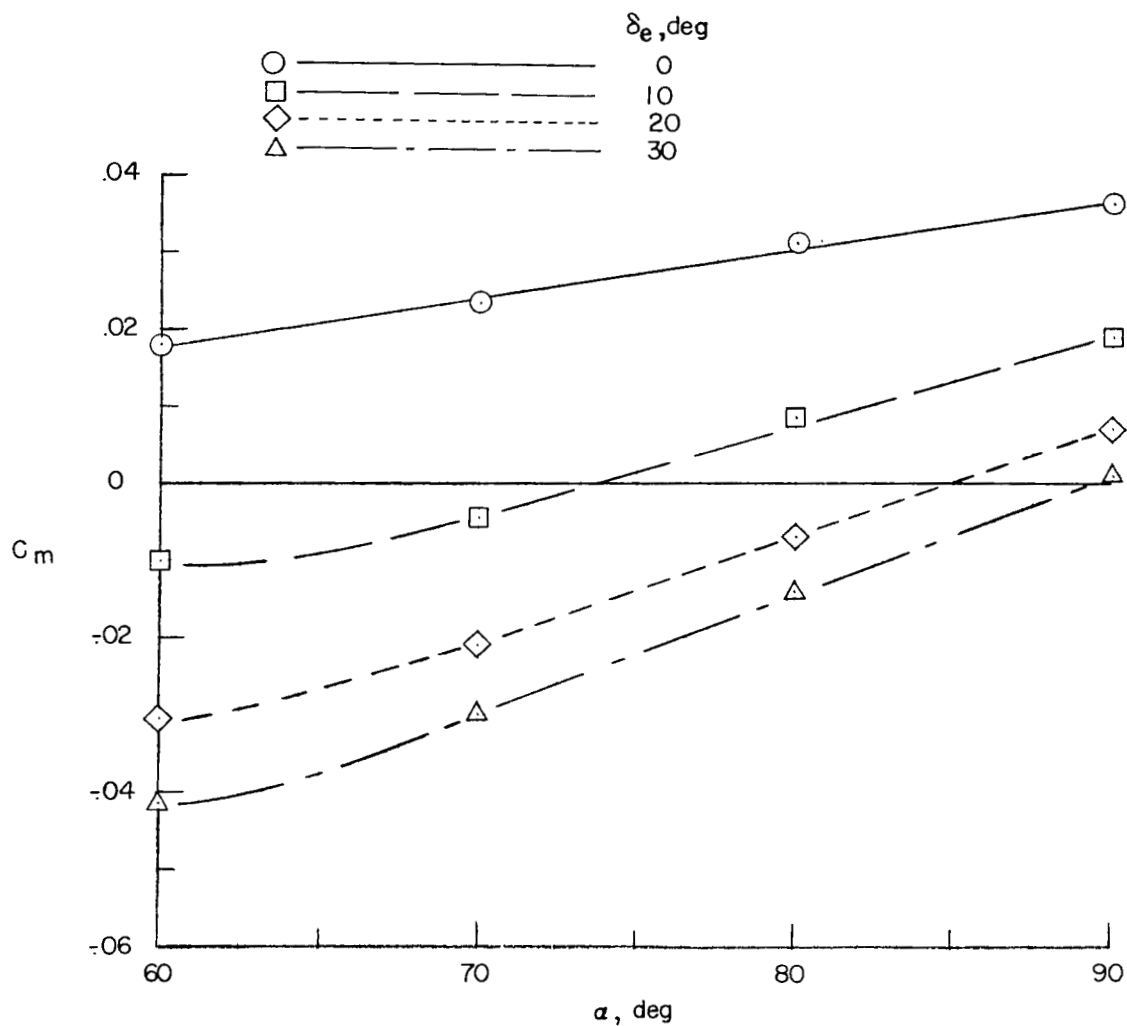


Figure 6.- Variation of pitching moment with angle of attack for various elevator settings. Height, ∞ ; $V_z/V_{s\infty} = 0.14$.

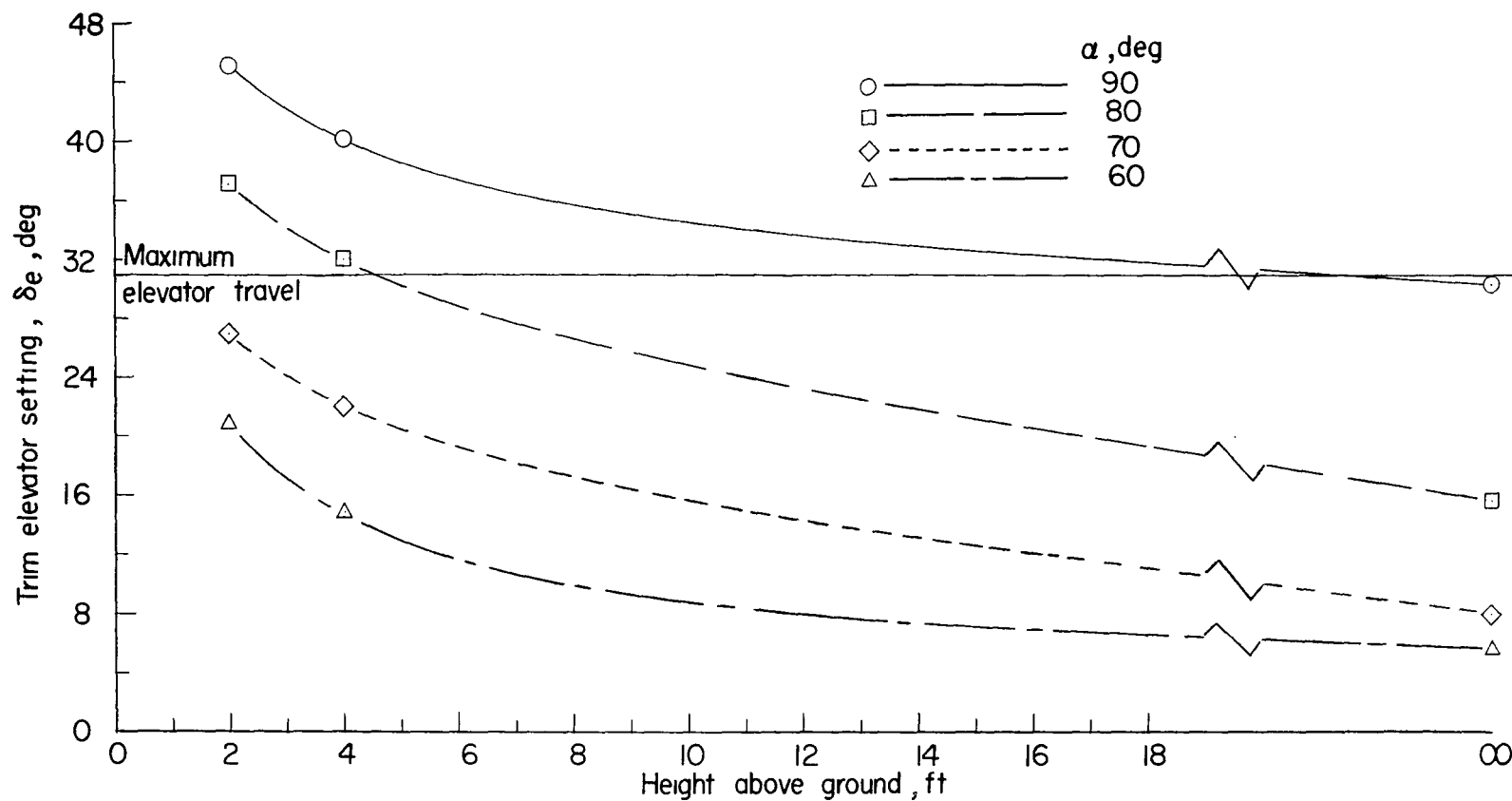


Figure 7.- The effect of height above the ground on elevator required for trim. $V_z/V_{S\infty} = 0.14$.

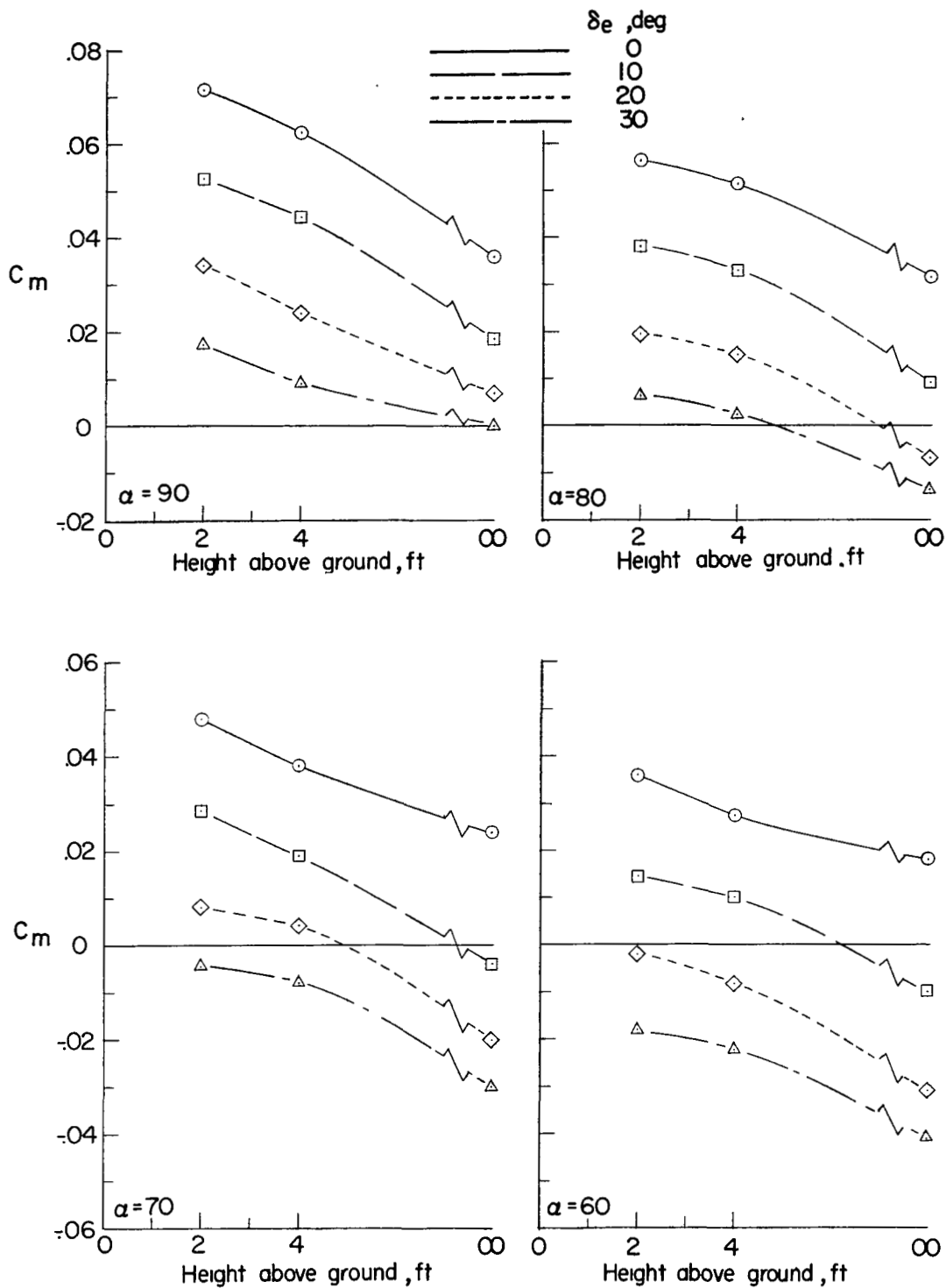


Figure 8.- Elevator effectiveness for various heights above the ground.
 $V_z/V_{S_\infty} = 0.14$.

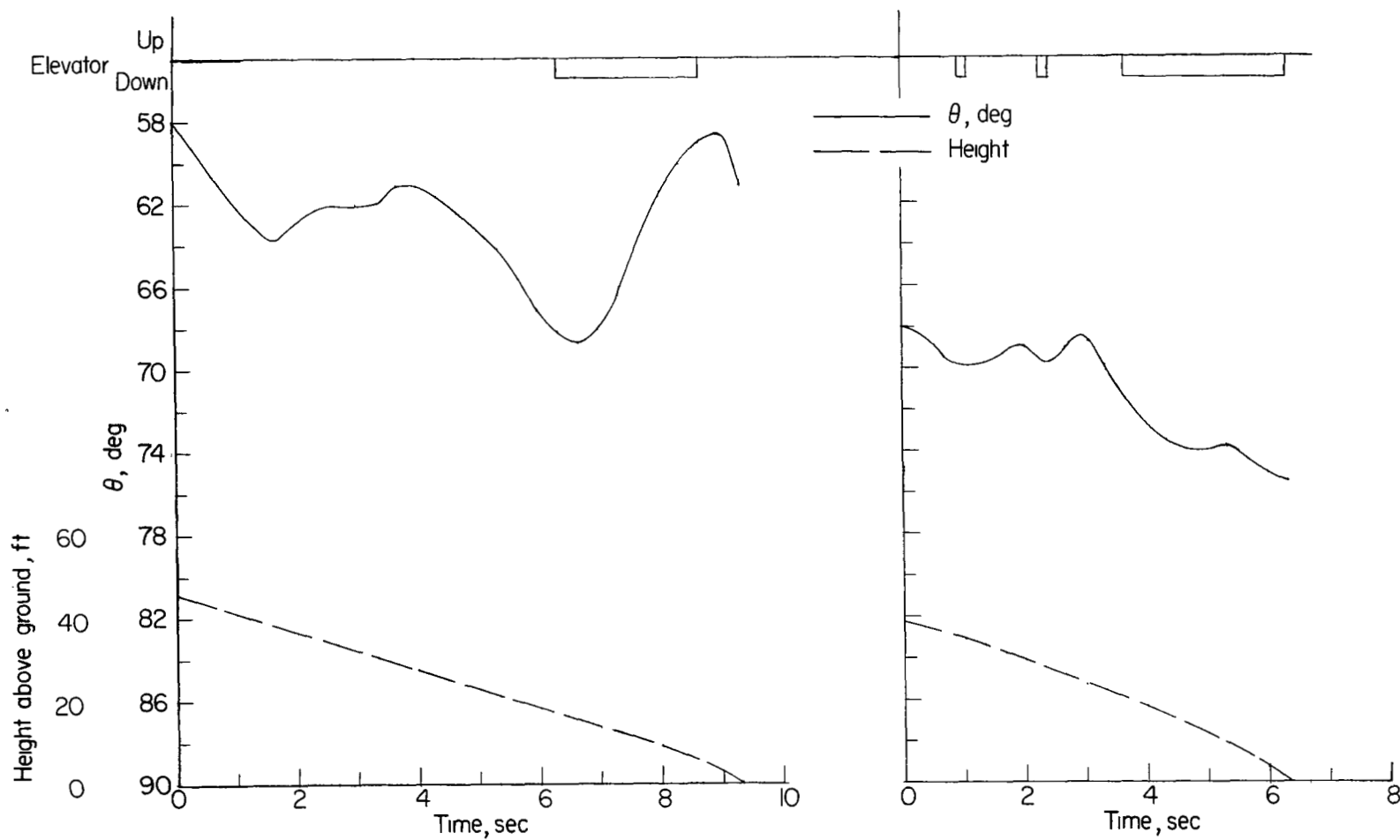


Figure 9.- Flight records of successful landing approaches in headwinds.
 $V \approx 20$ to 30 knots (full scale); time and distances are full scale.

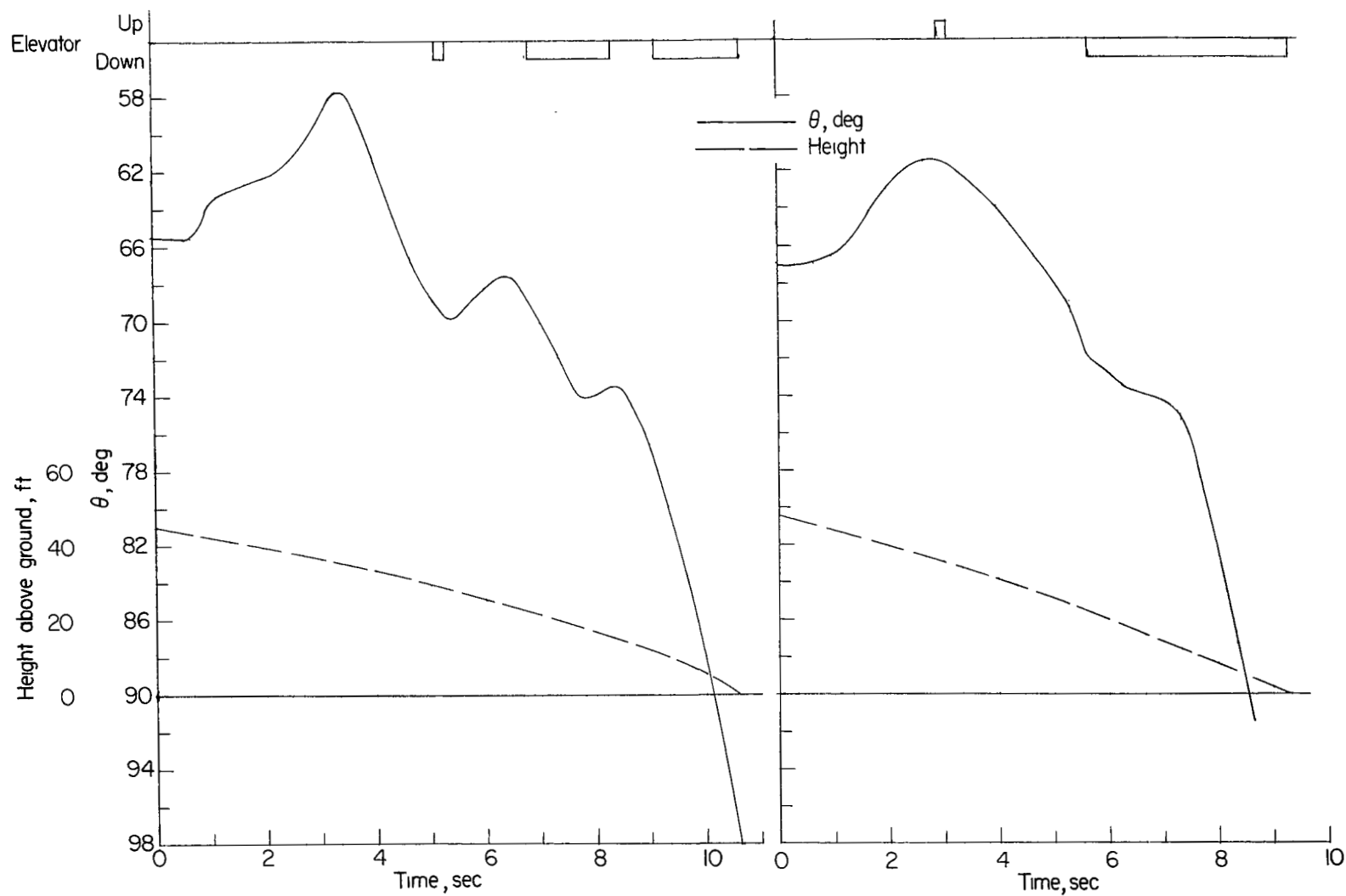


Figure 10.- Flight records of unsuccessful landing approaches in headwinds.
 $V \approx 20$ to 30 knots (full scale); time and distances are full scale.

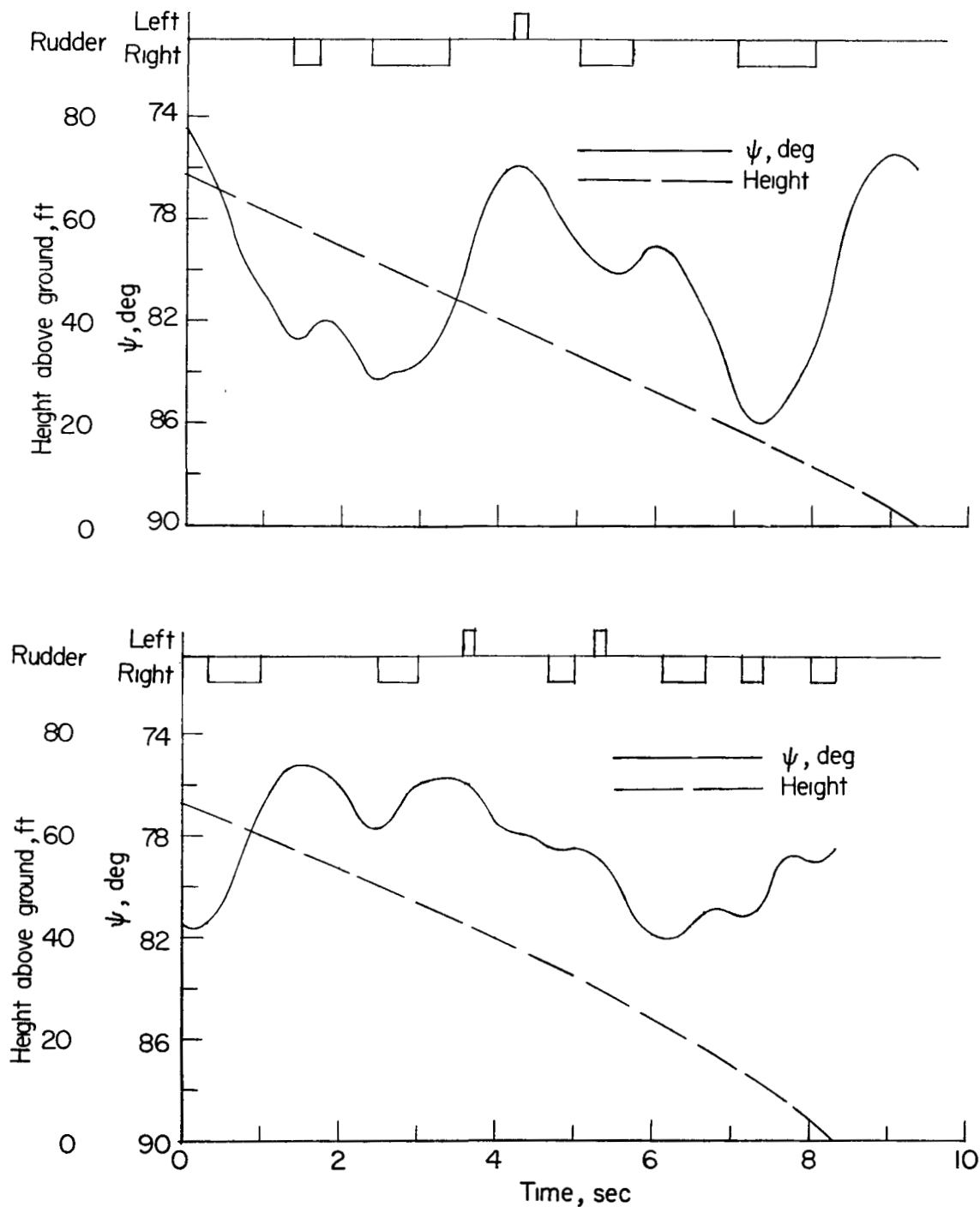


Figure 11.- Flight records of successful landing approaches in crosswinds. Right wing upwind; $V \approx 15$ to 20 knots (full scale); time and distances are full scale.

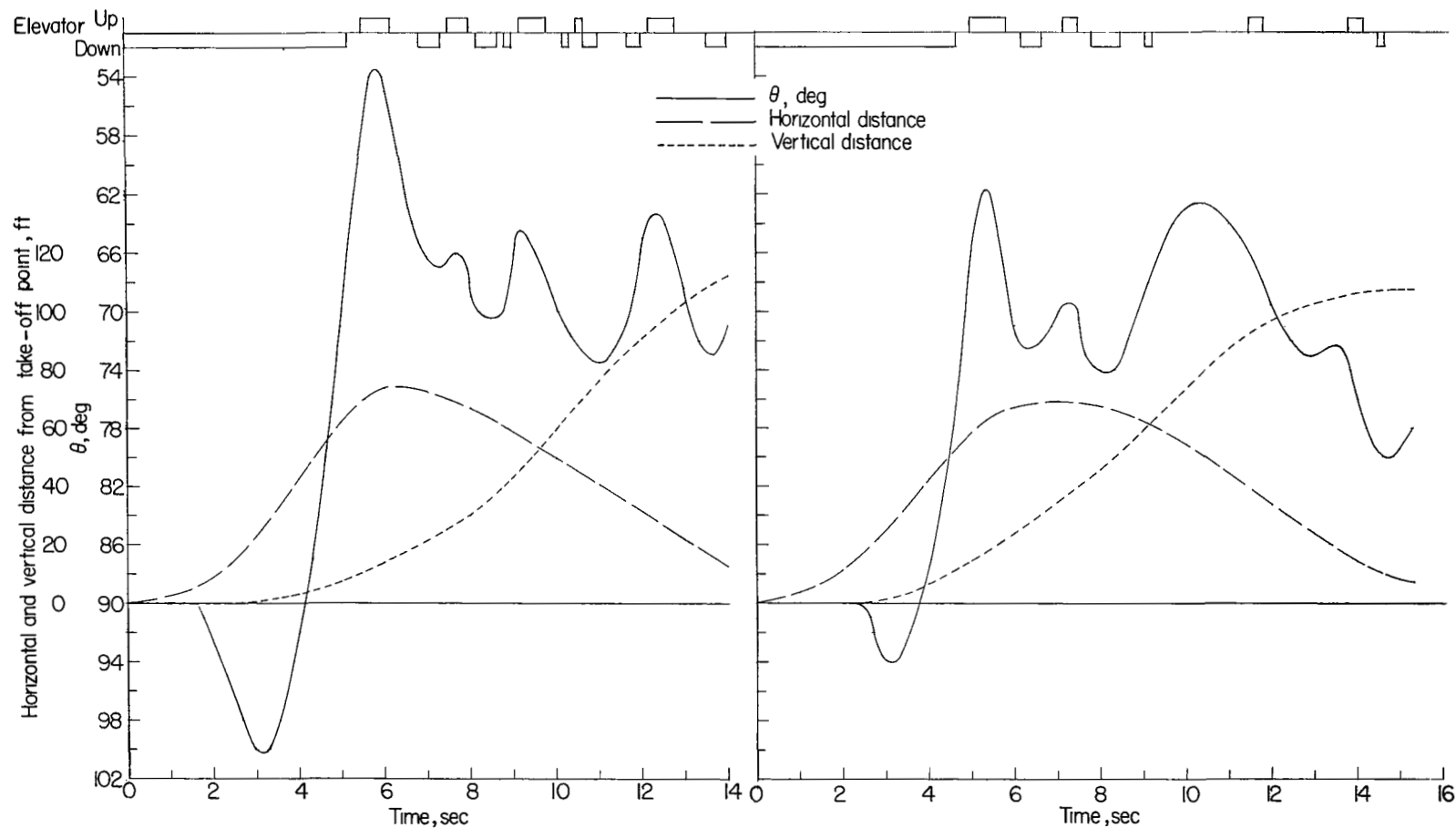


Figure 12.- Flight records of unrestrained take-offs in headwinds.
 $V \approx 15$ to 20 knots (full scale); time and distances are full scale.

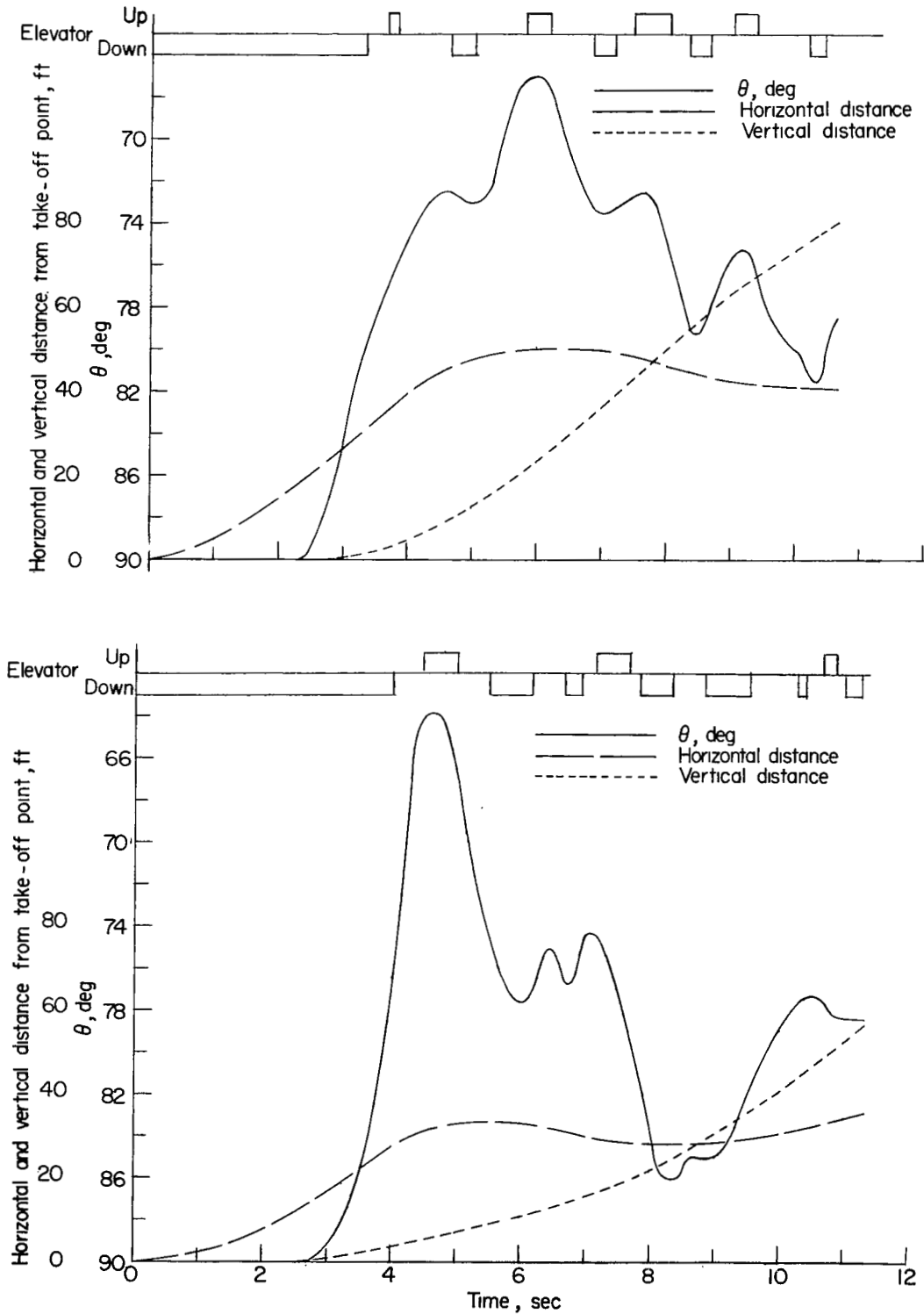


Figure 13.- Flight records of unrestrained take-offs in headwinds.
 $V \approx 10$ knots (full scale); time and distances are full scale.

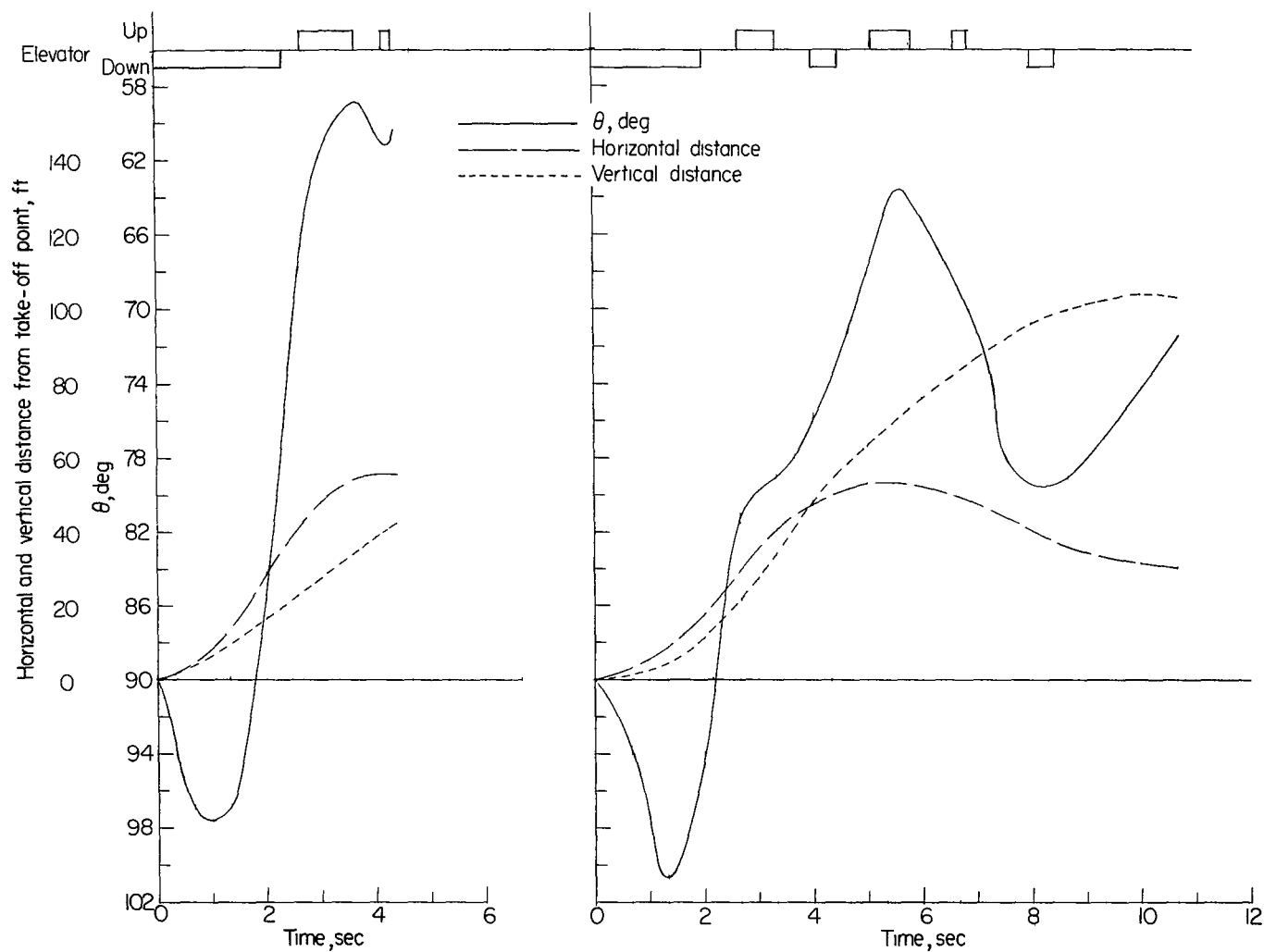


Figure 14.- Flight records of restrained take-offs in headwinds.
 $V \approx 15$ to 20 knots (full scale); time and distances are full scale.

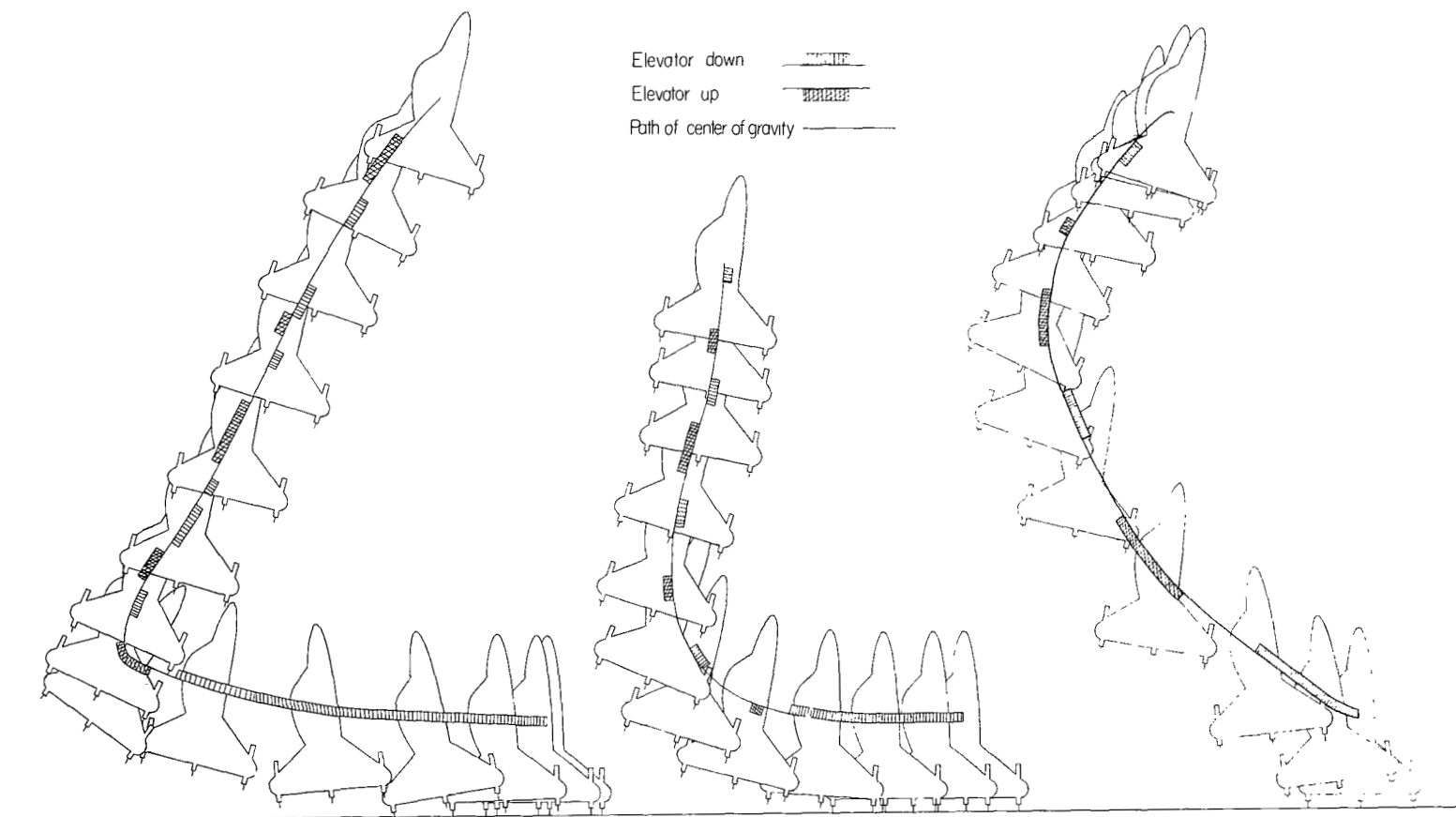


Figure 15.- Pictorial illustrations of take-offs in headwinds. Profiles plotted for 1-second intervals (full scale).

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